eLaunch Hypersonics

an Advanced Space Launch System

Prepared by the NASA Multi-Center EHLV Team

6/1/2010

Summary

This presentation describes a new space launch system that NASA can and should develop. This approach can significantly reduce ground processing and launch costs, improve reliability, and broaden the scope of what we do in near earth orbit.

The concept (not new) is to launch a re-usable air-breathing hypersonic vehicle from a ground based electric track. This vehicle launches a final rocket stage at high altitude/velocity for the final leg to orbit.

The proposal here differs from past studies in that we will launch above Mach 1.5 (above transonic pinch point) which further improves the efficiency of air breathing, horizontal take-off launch systems.

The approach described here significantly reduces cost per kilogram to orbit, increases safety and reliability of the boost systems, and reduces ground costs due to horizontal processing.

Finally, this approach provides significant technology transfer benefits for our national infrastructure.

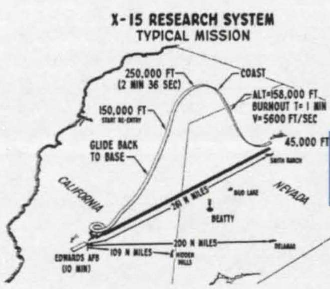
Why We Need a New Launch System

- Multistage rocket-based, space launch systems demonstrate a reliability of roughly 1 failure per 100 flights and costs greater than $10K/kg to LEO.
- By comparison, commercial aircraft exhibit one loss per 10M flights.
- Increasing reliability and decreasing costs of rocket based launch systems are so diametrically opposed as to be inconceivable, especially for the large changes needed (factors >10).
- eLaunch Hypersonic Launch Vehicles (EHLV) holds the technical potential for a breakthrough in these areas, where the US could lead the world in reliable, low cost access to space.

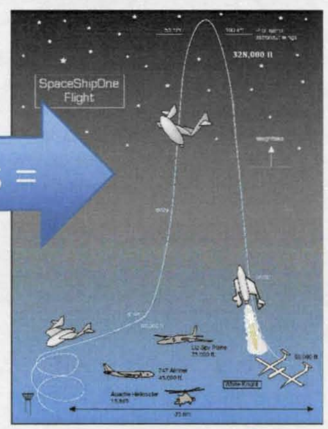
By combining NASA's knowledge in propulsion, aeronautics, launch vehicles, and vehicle integration and processing, we can achieve a significant LV technology advancement.

The eLaunch/Hypersonics Business Case

- The Government's business is to conduct high risk research to maintain the technological lead in global economies
  - X-15 + 40 years = White Knight
  - Mercury-Atlas + 40 years = SpaceX FALCON
  - eLaunch Hypersonics + ? years = commercial high volume, low cost, access-to-space



+40yrs =



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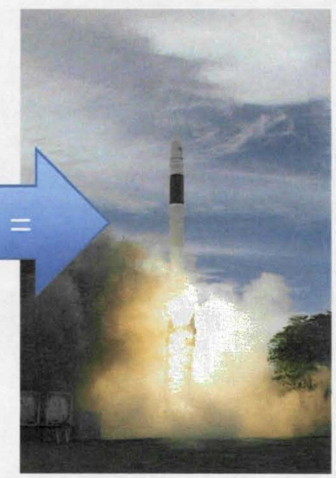


Alignment with NASA Goals

- "…hypersonics research focuses on long-range, fundamental and multidisciplinary research to enable air-breathing launch vehicles with improved reliability for lower cost and more routine access to space." Aeronautics Budget Page 20.
- "The Space Technology Program will improve the Nation's leadership in key research areas, enable far term capabilities, and spawn game-changing innovations to make space travel more affordable and sustainable…A suite of game-changing space systems discoveries are within our nation's grasp. With a stronger focus on technology development, the intellectual capital at NASA's field centers will be utilized to deliver solutions to some of our nation's grand technological challenges." Space Technology Budget page 4.

EHLV is a game-changing space launch technology which supports all long term NASA mission objectives.

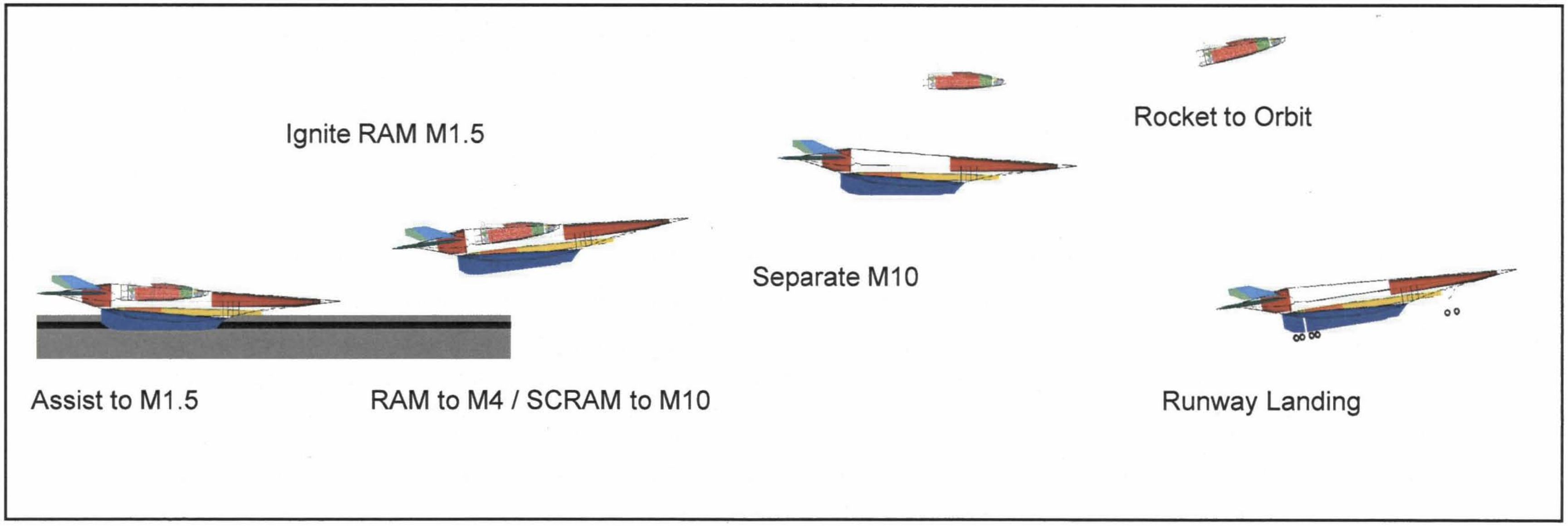
Background

- NASA has funded several past programs to explore the concept of launching space payloads via an air-breathing first stage. These studies have all shown very significant advantages in all aspects of space launch: cost, lift off weight, reliability, re-usability, environmental impacts…but with significant technology development challenges.
- These programs have also shown that a horizontal, rail-launched system can reduce lift off weight and cost.
- A successful EHLV could replace current rocket launch technology with significant potential decreases in costs and increases in reliability, if sized to take advantage of higher launch rates for lower mass and volume payloads, such as small to medium size satellites.

Past projects were canceled or down-scaled due to Agency funding priorities not by technical barriers.

The eLaunch/Hypersonics Business Case

- Any one of these eLHV technologies can revolutionize the launch industry:
  - Air-breathing supersonic booster
  - Fly-back booster
  - Hypersonic stage
  - Horizontal Launch Assist



EHLV Description

- The envisioned eLaunch system would consist of a single track running West to East, up to two miles long (operational system) and launch over the Atlantic.
  - Vehicles and payloads would be launched at sufficient speed to efficiently size high speed air breathing propulsion (est. Mach 1.5)
  - Track length would include an abort decelerator section to improve safety and recover the carrier sled.
  - Sonic boom mitigation will require a modest Range clearance area over the water.
  - Track length will depend on acceleration limitations of the vehicle and power supply limitations.
- The First stage would fly to high altitude and velocity, say about Mach 7-10, then release conventional rocket-powered upper stage with payload.

Studies show an increase in payload mass fraction to orbit of 100% or more (reduces gross lift off weight by 50% or more)

Hypersonic Lifter

- Boost vehicles will be highly reusable and will operate in a more benign environment than Shuttle, with resulting lower costs, higher reliability, and more rapid turn-around; operability is more like an aircraft than a rocket for the boost vehicle.
- Multi-cycle, air breathing propulsion will use oxygen from the atmosphere, largely eliminating the weight of on-board oxidizer.
  - Nearly half the mass of current multistage rockets is LOX.
  - The specific propulsion will change as the velocity changes. From launch to Mach 3+, high speed turbines and/or internal rockets can be used; then a Ramjet is used through about Mach 6, which transitions to a Scramjet out to Mach 10+.
  - During the return flight of the reusable boost vehicle, the low speed propulsion could be restarted to provide for a "go-around" capability to enhance recovery safety.
- The eLaunch approach minimizes size and weight of wheeled landing gear.

Why NASA should pursue this approach

- It would enable routine launch-on-demand activities, such as LEO asset resupply and potentially space tourism; very high pay-off.
- The technologies are closely aligned with the U.S. Technology Infrastructure needs, such as transportation (high speed rail, green aviation), peak energy storage (flywheels), and DoD flight technology requirements.
- If developed somewhere other than the US, we risk a competitive loss of our core launch capability, both Government and commercial.
- This effort will require expertise from most or all of the NASA Centers and will stimulate a strong collaboration between the Space and Aeronautics segments of NASA.
- The project will eventually result in a robust and highly competitive commercial launch business.
- It will be viewed by the public as the kind of cutting edge work that NASA should be doing.

Team Membership and Key Center Roles

Center	Roles/Interests	Team Members
Langley Research Center	Hypersonic vehicle, integrated performance, hypersonic propulsion, airframe structure	**Paul Moses**, Kenneth Rock, Jeffrey Robinson, John Martin, David Glass, Vincent Schultz
	Green Aviation	Faye Collier
	eLaunch Technology	Erik Vedeler, Robert Young
Glenn Research Center	Hypersonic propulsion, high-speed turbines	**Paul Bartolotta**
	Multiple technology launch tracks	J. Michael Pereira
	Electric power	Ray Beach
Dryden Research Center	eLaunch technology	**Kurt Kloesel,** Ross Hathaway
Goddard Space Flight Center	eLaunch technology/flight test	**Michael R. Wright**
Kennedy Space Center	eLaunch physics	**Stanley Starr,** Bob Youngquist
	eLaunch test bed	Mike Vinje, Anthony Harris
Marshall Space Flight Center	rocket based upper stage	House, Kenneth W.
	eLaunch Technology	Ronald Litchford
Ames Research Center	TPS Hypersonics	Dan Empey Sylvia Johnson

Project Organization

DRAFT

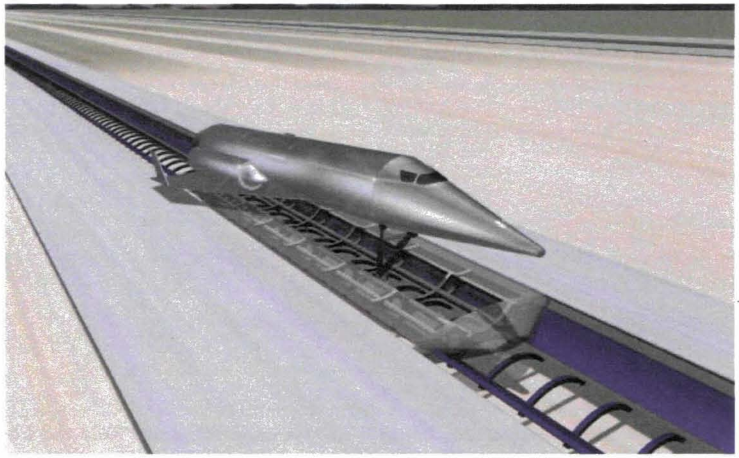
- **Project Management** – KSC
  - **Systems Engineering & Integration** – LaRC, KSC, GSFC
  - **Ground Systems** – KSC
    - Launch Facility – KSC
    - Power Systems – KSC, GRC
    - EML Technology – GSFC, KSC, DFRC, MSFC
    - Gas Technologies – GRC, KSC, MSFC
  - **Flight Systems** – LaRC
    - Booster Airframe – LaRC, DFRC, ARC
    - Booster Propulsion – LaRC, GRC, ARC
    - Rocket Stage – MSFC
    - Flight Testing – LaRC, DFRC
  - **Integrated Testing** – KSC, LaRC
    - Ground – KSC, LaRC, GRC
    - Flight – LaRC, DFRC GRC

Current Technology Status: eLaunch

- Electromagnetic linear propulsion is well established technology field (e.g. high speed trains, Navy's Electro-Magnetic Aircraft Launch System (EMALS), roller coasters).
- Three available technology approaches are linear induction motors, synchronous motors, and Lorentz force (Rail Gun)
  - Induction motors are most mature technology but issues exist for high speeds (300 + FPS)
  - Synchronous motors have advantages but need development.
  - Rail Guns used for high speed (10,000 FPS) but currently used to accelerate small objects.
- Current technology is mature for low speed (<Mach 0.5) but not developed for the speeds needed here.
- Magnetic levitation eliminates friction but has stability issues as speed and vibration increase. Alternative sled interfaces will be studied.
- All potential approaches will require R&D in energy storage, power switching and other key component areas. High speed systems (above Mach 0.5) are at approximately TRL 2 to 3.
- If required, KSC can build a rocket (gas) powered track sled to decouple the hypersonic vehicle technology development from the electric track technology.

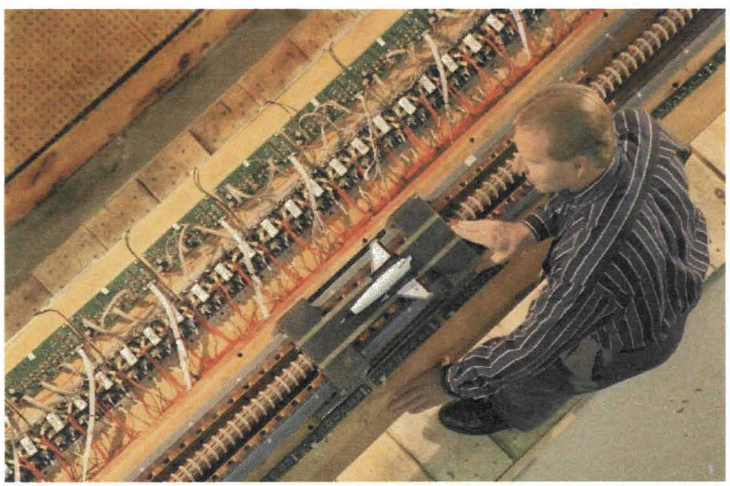
All eLaunch technologies offer significant technology transfer opportunities to Energy and Military sectors

eLaunch Heritage Concepts



Maglifter/Argus

PRT Test Track at MSFC



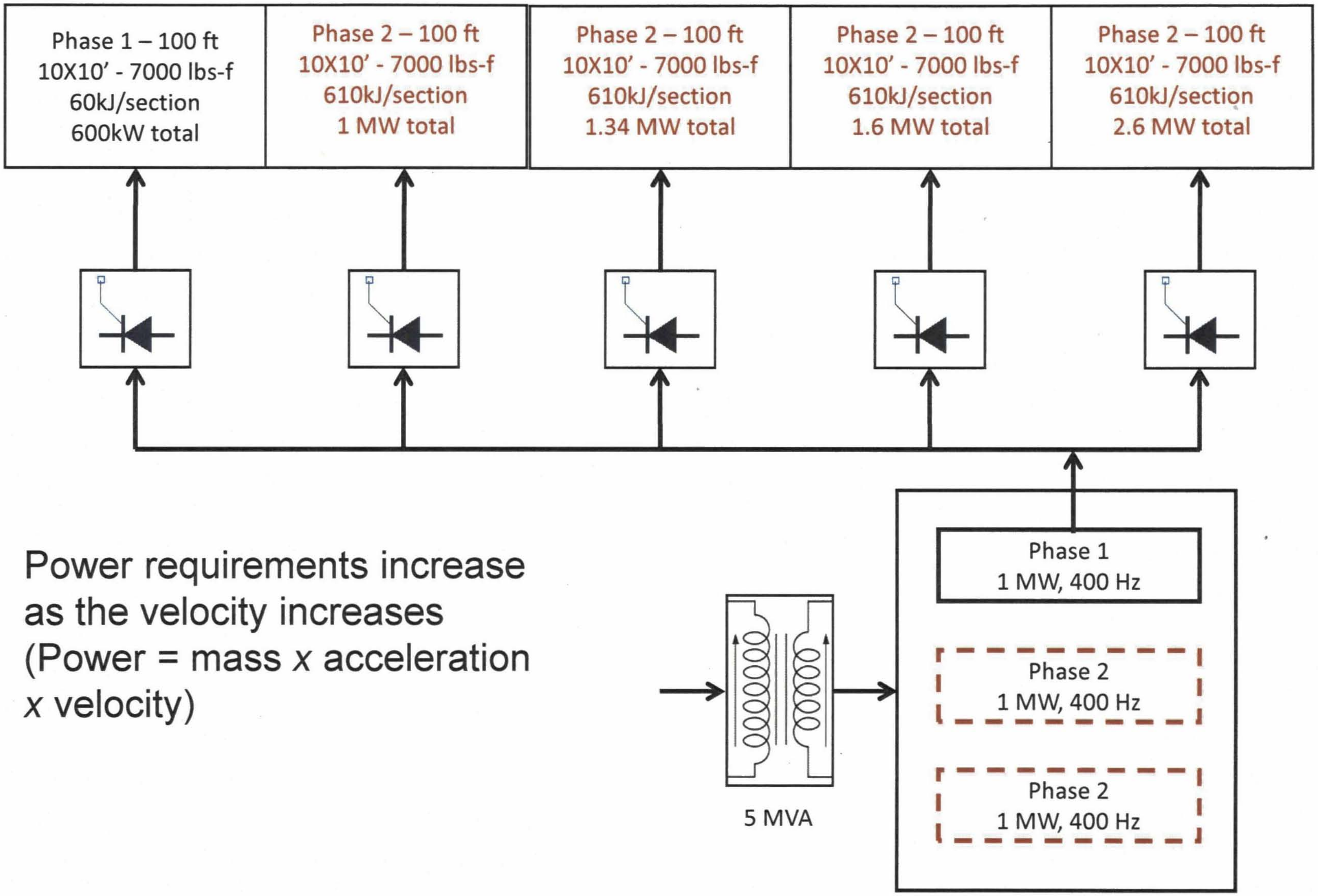
Foster Miller Track at KSC

Currently at Florida Tech

Navy EMALS

EMALS to be installed on next generation Carrier under construction at Newport News

eLaunch Acceleration Track (Notional)



Power requirements increase as the velocity increases (Power = mass *x* acceleration *x* velocity)

eLaunch Track Build-up

- Phase 1 track can build 100 ft of Phase 2 track
  - In order to increase the TRL track from current, one plan would be to use ~5000 lb-force motors for Phase 1 track implementation.
  - Cost of this route does not severely impact budget and allows for TRL gain 1st year
  - 1 MW, 400 Hz power converters can be paralleled to meet final Track 2

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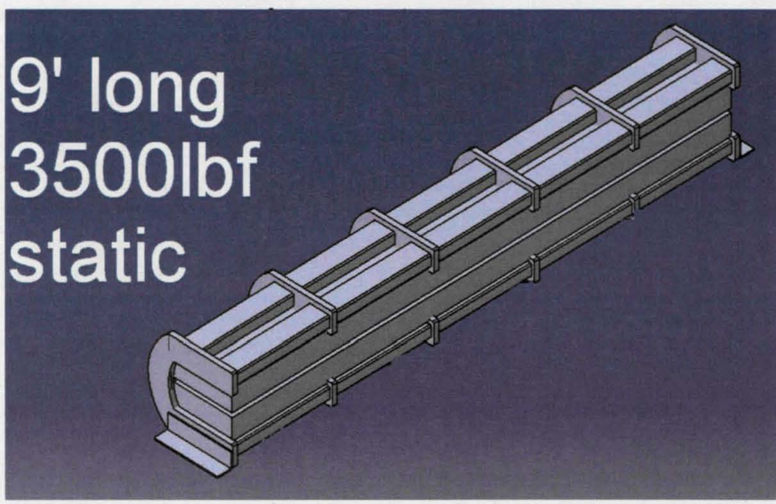


Reference Double Sided Linear Induction Motor (DSLIM)

Two DSLIM motors placed front to front Dual C-C configuration for 7000 lbf

Facility Locations at KSC

Initial facility will be built beside Crawler-way to Pad A where power is plentiful.

Launch will occur over the Atlantic Ocean.

Current Technology Status: Hypersonic Lifter

- The US has been pursuing hypersonic propulsion technology since the 40's.
- NASA has an on-going Program under Aeronautics which has recently reached Mach 8 plus using aircraft launched rocket boosters to an initial Mach # of 5.
- EHLV will require development of integrated propulsion systems to span low to high Mach numbers (1.5-10) and transition between systems.
- Benefits of EHLV improve dramatically with launch Mach number. Mach 0.5 would be the threshold for an testing system with Mach 1.5 as an operational requirement.
- Current test programs (Hyper X, X-43a, X-51) have advanced aero-dynamics, asymmetric staging, TPS, Guidance, Navigation and other component technologies required for EHLV.

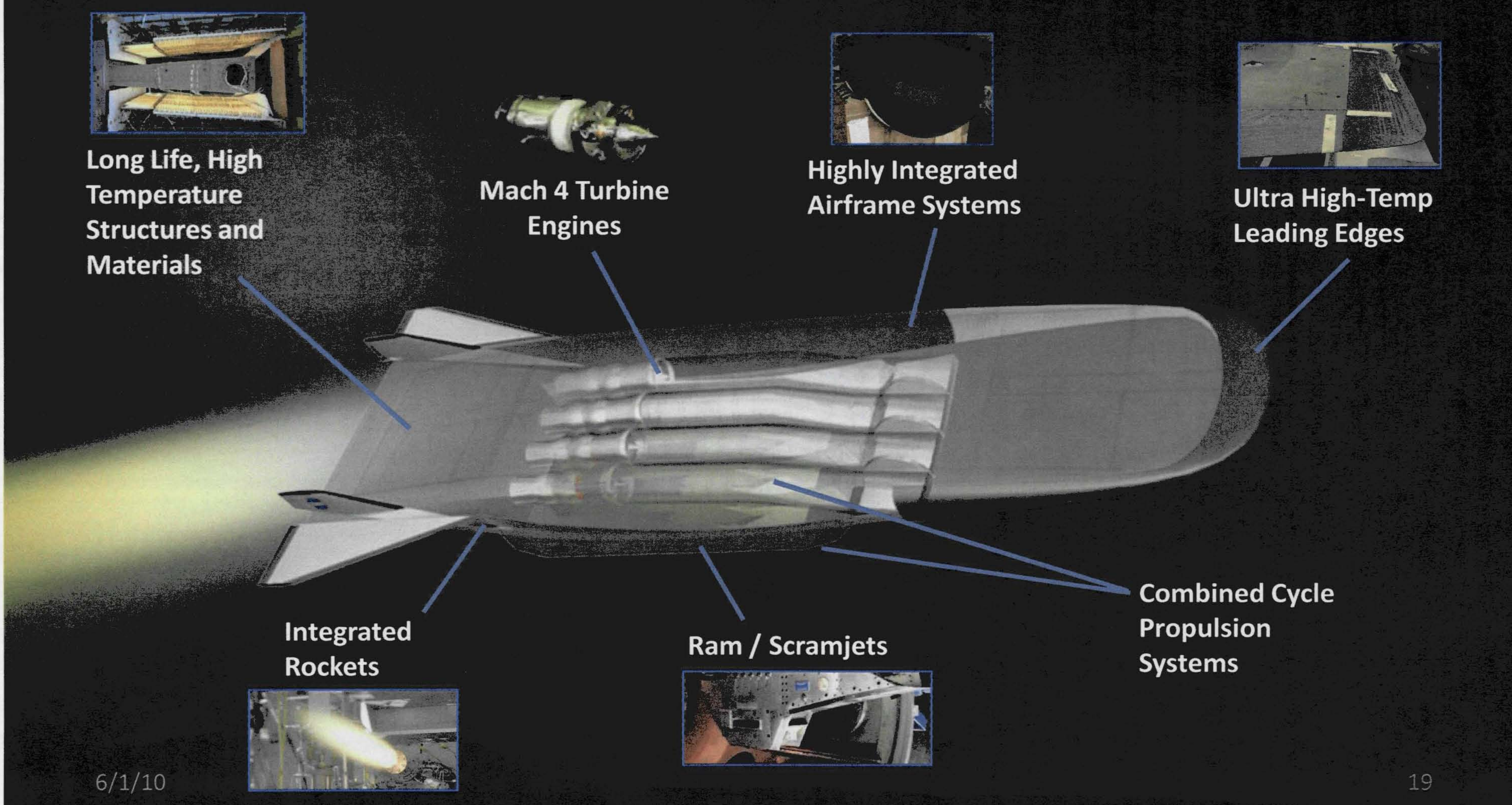
p3

Advances in Hypersonic flight system technology are recognized to deliver significant benefits for transportation sector and DoD.

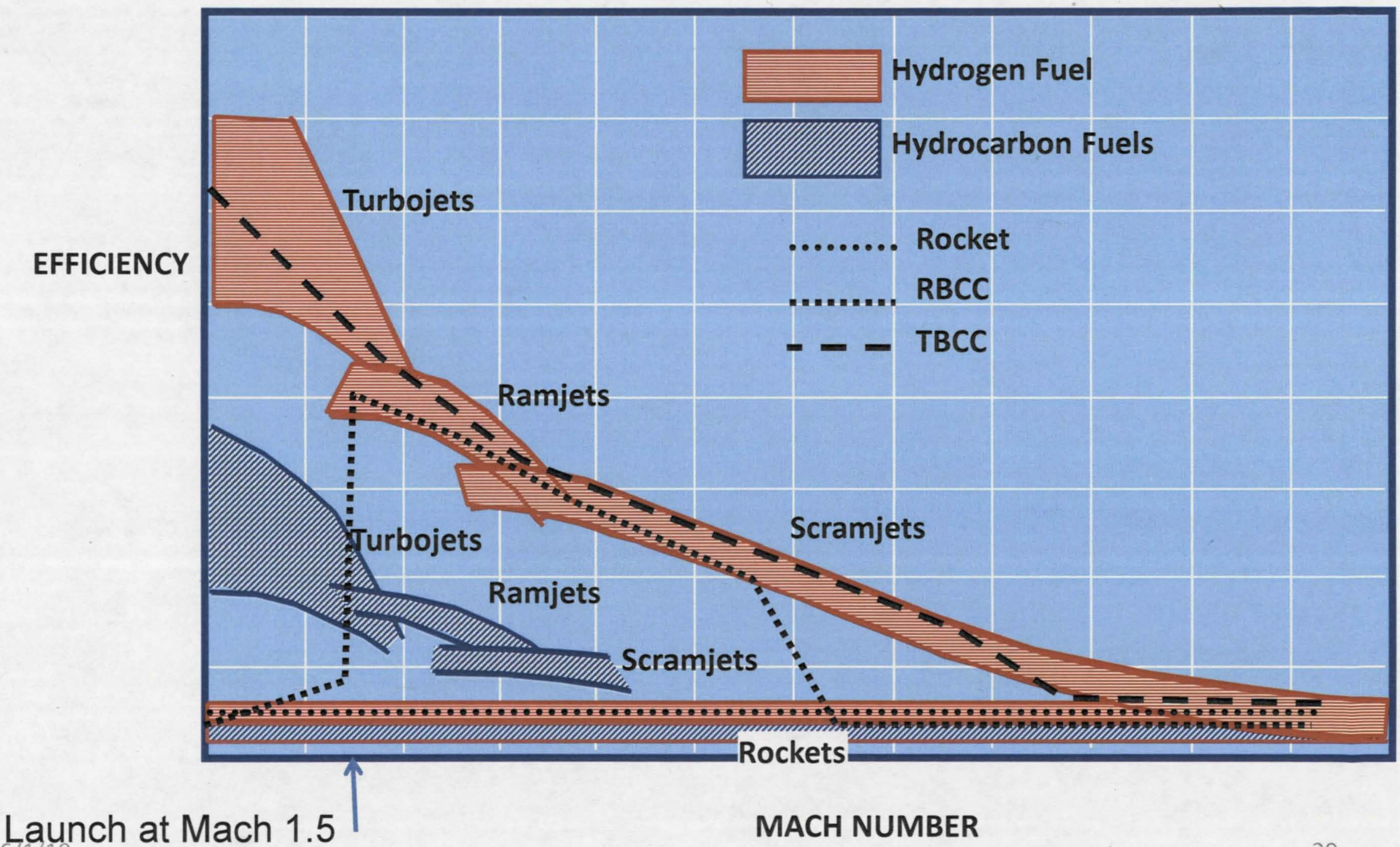
Slide 18

p3 It is highly unlikely we would ever launch in the transonic regime. It is also unlikely we would ever be at Mach 3 at sea level. We must be careful of our credibility. I would suggest we tone this down to about Mach 0.5 and up to Mach 0.85
plmoses, 3/11/2010

Cutting Edge Hypersonics Technologies for Future, Aircraft–like Operations



Air Breathing Propulsion Significantly Increases Propulsion Efficiency as Compared to Rockets



Present Tech Challenges for Reusable Hypersonic Propulsion

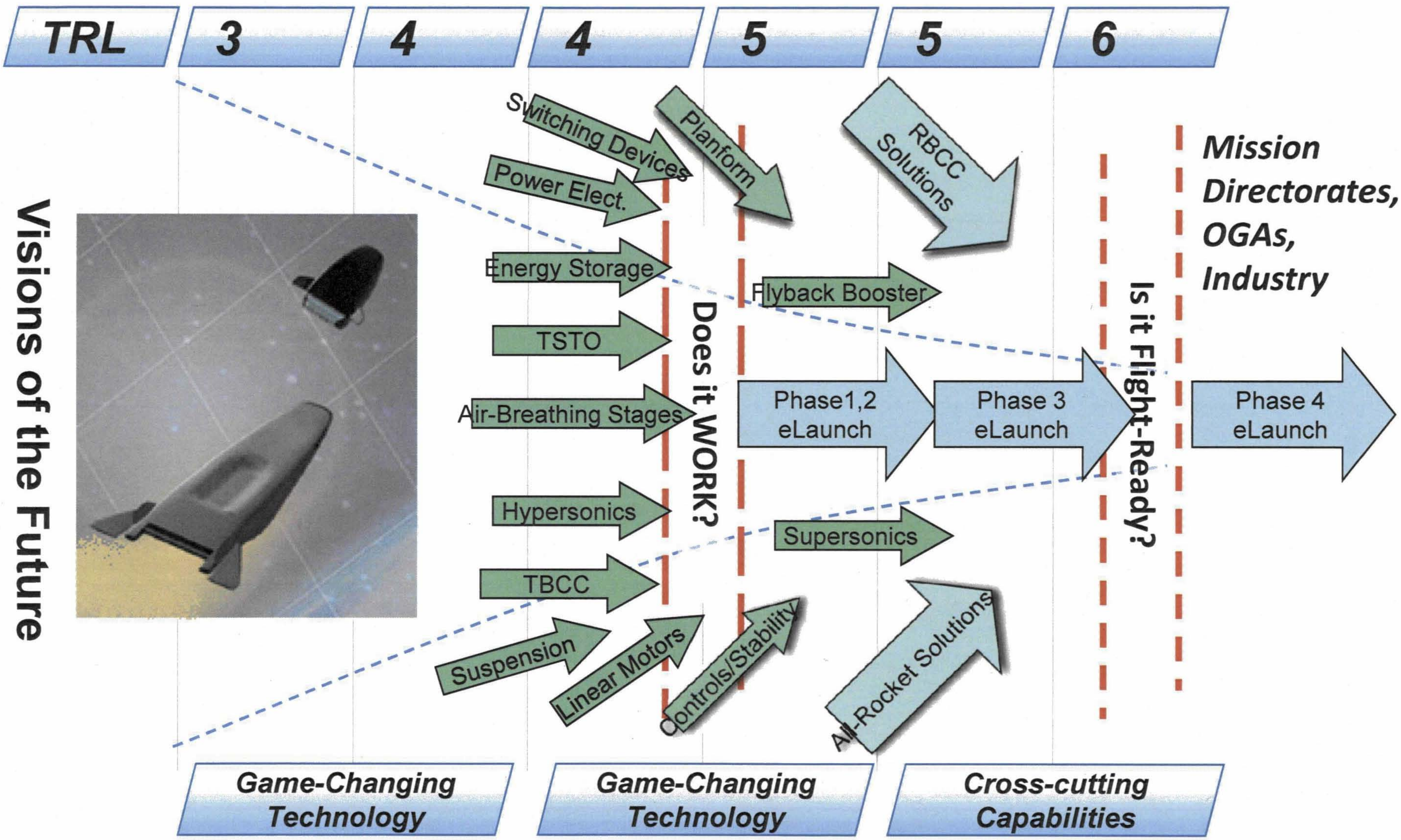
1) Wide operating range ground/flight tests for both Scramjets & High Mach Turbines
   - Present tests for scramjets are discrete Mach speeds
   - X43-A flights were limited in speed range
   - No ground-based altitude facilities exist for wide operating range tests
   - Must have longer duration flight tests
   - Same for high Mach turbines at speeds above Mach 2

2) Mode transition between high speed (scramjet) & low speed (RTA) propulsion systems
   Shared inlets & nozzles could stall compressors or unstart inlets
   Ground-based altitude facilities are limited on size & wide operating range
   Transition Speed margin between RTA & Dual Mode Scramjets

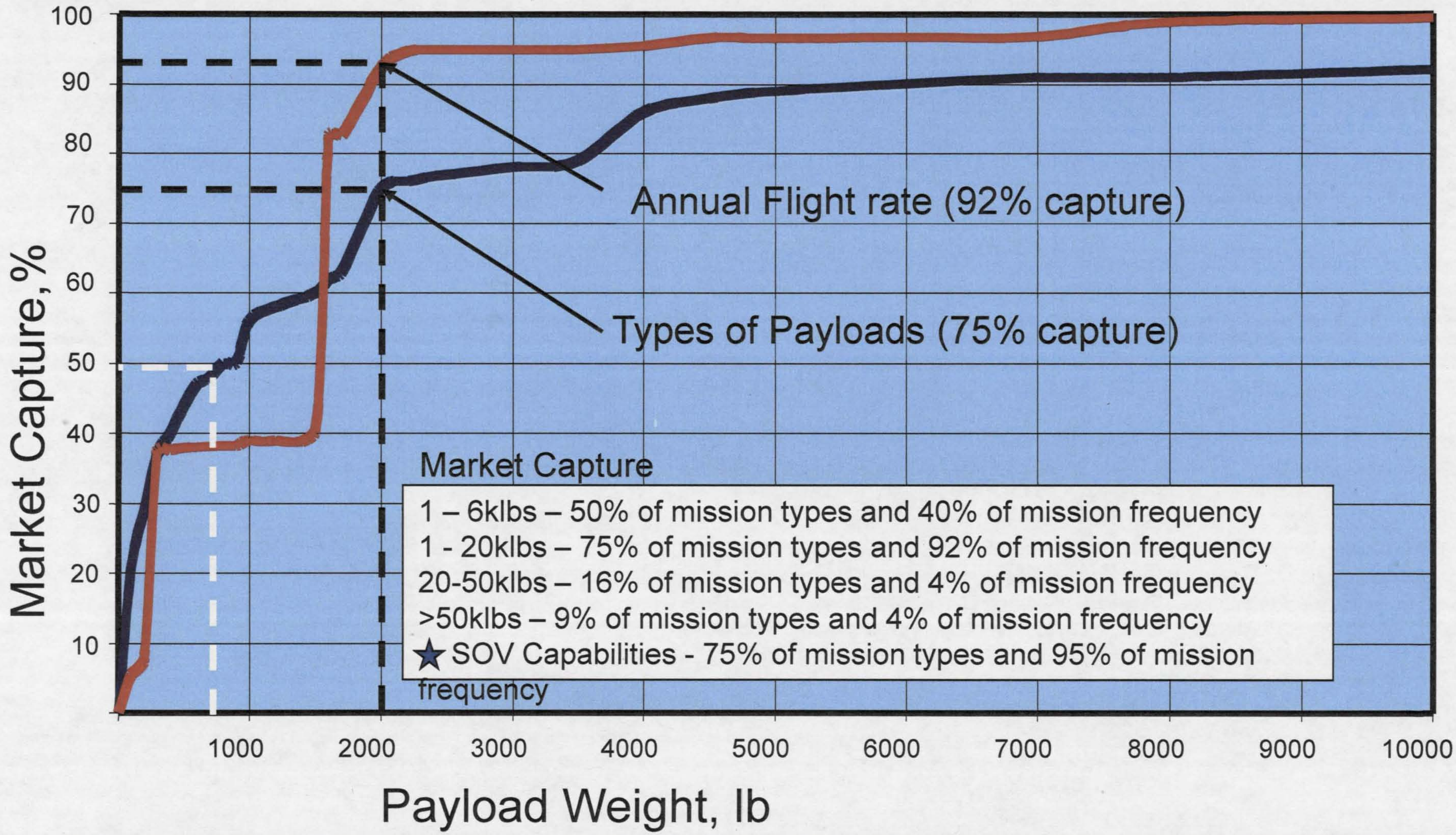
3) High Mach Turbines (RTA) & Dual Mode Scramjets
   Lower ignition speeds for Scramjets (M<4)
   Higher Speed Turbines such as an RTA (M>4)

4) Thermal Management & High temperature materials
   Advanced HEX for cooling air, fuel cooling and actively cooled scramjet panels
   Leading edges for inlets
   High temperature seals & bearings

EHLV Sub-Systems are at low to mid-TRL



Commercial/Civil/Military Launch-Market Survey



Various market surveys indicate <3500 lb payload good for initial launch market capture, but need vehicle growth-versions to reduce acquisition cost of follow-on increased launch payload capability.

Proposal for FY11

- Organize a multi-Center Program; develop a Program Plan, including an optimization trade study.
- Design and begin construction of a test bed at KSC that can grow into an operational launch capability; maximize Shuttle facilities re-utilization.
- Re-invigorate Hypersonic propulsion activities at LaRC, GRC, ARC, DFRC to perform tasks to resolve and demonstrate solutions to key propulsion and airframe issues.
- Identify network of Universities and businesses with related interests and identify roles and scope for future contracts and partnerships.

Notional Long Term (10 year) Plan

- Phase 0, 1 year: Planning, Program Management, establish test facilities, Configuration development studies
  - Organizing, planning, and long lead construction; phase 1 planning.
- Phase 1, 1 year: Launch subsonic model (3 meter class vehicle, 500 lbs, Mach 0.8 launch, low speed turbine based model
  - Hands On Learning: Verify on-track stability, linear induction, electronic power switching, abort capability, normal separation, flight, recovery) using near existing track and vehicle technologies; phase 2 planning
- Phase 2, 2 years: Launch supersonic capable model (10 meter class, 10klbs, Mach 1+ launch, flight incrementing to Mach 4)
  - Scale energies, mass, velocity. Demonstrate transition from rail to high speed turbine flight and landing. Much larger rail systems, more advanced airframe and propulsion.
- Phase 3, 3 years: Launch hypersonic model (15 meter class, 30klbs, 1500 FPS launch,
  - operate RAM/SCRAM systems, achieve Mach 6+, study rocket based payload separation at high speeds.
- Phase 4, 3+ years (vehicle size and weight dictated by requirements) :
  - Initial small satellite capability, full cycle demonstration at optimum speeds and staging. Highly re-usable technologies. Initial operational prototype space launch system.

Slide 25

p1 note prior comment about launch velocity
plmoses, 3/11/2010

Cross Cutting Technologies

- **Transformative technology development and flagship technology demonstrations to pursue new approaches to space exploration**
  - Mass transfer from the lunar surface
    - Inductive power to allow contactless power transfer for ISS, EVA and surface elements
- **Research and development on heavy-lift and propulsion technologies**
  - EHLV as "new" approach to two-stage to orbit (TSTO) hypersonic launch propulsion
  - Increased mass-to-orbit capability, with less on-board fuel required (partner with DoD)
- **Cross-cutting technology development aimed at improving NASA, other government, and commercial space capabilities**
  - Guided surface transportation: urban low-speed, intercity high-speed (partner with FRA DoT)
  - Highways: zero-emission linear motor systems to reduce emissions & improve fuel economy of traditional vehicles, and enable unlimited range for electric vehicles (partner w/ FHWA)
  - Electric power storage, coupling, recharging, and regeneration systems (partner w/ DOE)
- **NextGen and green aviation**
  - Advance beyond simply developing biofuel-burning aircraft engines
  - Linear motors for taxiing, inductive power coupling for zero-emission idling
  - EML takeoff and landing with power regeneration (partner with FAA, DOE)

Contacts for More Information

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